ARCHES NATIONAL PARK
RESEARCH SUMMARY 2011

1) Study Title:
Permit No.: ARCH-2010-SCI-0001
Principal Investigator: Ed Baker
Purpose of Scientific Study:
Findings/Accomplishments for 2011:

2) Study Title: Riparian Ecological Site Study of Arches National Park
Permit No.: ARCH-2011-SCI-0001
Principal Investigator: Victor Parslow
Purpose of Scientific Study: The project is a study of the stream channel type and existing vegetation of the riparian areas in Arches National Park. This data is necessary to complete the riparian Ecological Site Descriptions for the Park.
Findings/Accomplishments for 2011: Riparian vegetation data was collected in the riparian areas of Arches National Park.

3) Study Title: Southern Utah Visitor Profile Study 2010
Permit No.: ARCH-2011-SCI-0002
Principal Investigator: Emmett Steed
Purpose of Scientific Study: The purpose of this study is to understand Southern Utah's tourists, who stay overnight and travel more than 50 miles from their homes. The research seeks to answer the following questions:
1. What are the demographic characteristics of Southern Utah visitors?
2. What relationships exist among Southern Utah visitors in regard to place of origin, Southern Utah destinations visited, transportation utilized, activities selected while in Southern Utah, and trip expenditures?
3. Are there seasonal differences in origin, destinations, activities, and expenditures?
4. What are the information sources utilized by Southern Utah visitors?
Findings/Accomplishments for 2011: The Utah Office of Tourism partnered with the Southern Utah University Hospitality Research Center to conduct a Central/Southern Utah Visitor Profile study. Visitors to four Central Utah Counties and eight Southern Utah Counties were asked to complete surveys that were designed by three Southern Utah University professors. Visitors were asked to complete the surveys in four different seasons. The surveys were completed by hand, by returning an e-mail attachment, or by going to a website. There were 1,113 useable surveys completed. Four research questions guided the survey and analysis. Each question is stated below with a summary of its key findings.
I) What are the demographic characteristics of Southern Utah visitors?
The majority of visitors to the Central/Southern Utah area were: 1) over 45 years old; 2) have a household income greater than $80,000; 3) spend $100 per day in lodging and $50 per day in food and beverage; 4) are married with no children under 17 years old in their household; 5) have at least a college education; and 6) visit National Parks frequently.
II) What relationships exist among Southern Utah visitors in regard to place of origin, Southern Utah destinations visited, transportation utilized, activities selected while in Southern Utah, and trip expenditures?
One of the most important findings was that geographic origin was not a valid predictor for places visited, activities selected, or expenditures made. In other words, no matter where people come from, once in Central/Southern Utah, they visit similar places, select similar

activities, and spend similar amounts of money. The further away a visitor lived from Southern Utah, the more likely she was to travel by airplane.
III) Are there seasonal differences in origin, destinations, activities, and expenditures?
There were distinct patterns in visitors' origins, destinations, activities and expenditures by season. For example, domestic visitors from Pacific states were more likely to visit in the spring and summer while mountain state visitors were more likely to visit in the fall and winter (X2=.000). International visitors vary by season as well. For example, English speaking tourists from Great Britain, Canada, Australia, and New Zealand were more predominant in the spring; Winter received the most returning visitors 74% (X2=.045). Destinations and activities varied by season as well. The destination seasonal patterns followed the activity patterns with national parks receiving the most visits in the summer and spring. The most popular activities included visiting national/state parks (79.5%), touring/sightseeing (70.4%), and hiking (65.2%). Visiting state/national parks increased in the spring and summer (X2=.020). Touring and sightseeing follows this same pattern (X2=.003), while hiking, as can be expected, decreases in the winter (X2=.027). Visitors spent more money in the summer, spending more on lodging (X2=.002), food (X2=.008), rental cars (X2= .025), recreation fees (X2=.004), and park fees (X2=.009) than in other seasons.
IV) What are the information sources utilized by Southern Utah visitors?
Southern Utah visitors stated the internet (82.6%), past experience (79%), and friends and relatives (63.5%) were either very influential or somewhat influential information sources.

4) Study Title: Structural development of accommodation zones in host and suprajacent sediments associated with the development of salt walls: implications for sub-surface hydrocarbon flow
Permit No.: ARCH-2011-SCI-0003
Principal Investigator: Stuart Clarke
Purpose of Scientific Study: Salt walls and related structures provide ideal geometries for the accumulation of hydrocarbons. However, these structures are poorly understood in terms of their three-dimensional geometry and dynamics, and are difficult to interpret using seismic reflection data alone. This study aims to characterise the geometry and development of fault systems related to the dissolution of salt walls and the subsequent collapse of the overlying sediments. Detailed field mapping and collection of geometrical measurements from Arches NP and surrounding areas will be used to construct three-dimensional computer models, which can be used to evaluate the development of some of these key structures, and to assess the impact that their geometry might have on the flow of hydrocarbons. The models will later be used to develop a structural framework with which to guide seismic interpretation across salt structures in active hydrocarbon provinces, such as the Gulf of Mexico and the U.K. Central North Sea.
Findings/Accomplishments for 2011: Field mapping and structural data collection has been carried out for key areas along the Moab Fault (near the entrance to Arches NP) and in Salt Valley. Data from the Moab Fault have been used to develop a three-dimensional computer model of the fault system, which is due to be completed following further field data collection scheduled for 2012. Similar models will be constructed in 2012 for equivalent structures in Cache Valley. Comparison of some of the structures observed within the Arches NP area with those interpreted from U.K. Central North Sea seismic data has provided some initial insights into their early stages of development.

5) Study Title: NCPN Integrated Riparian Monitoring in Arches National Park
Permit No.: ARCH-2011-SCI-0005 (NOTE: There is no permit 0004 for 2011.)
Principal Investigator: I&M (NCPN)
Purpose of Scientific Study: The National Park Service's Inventory and Monitoring Program (NPS I&M), in collaboration with 32 monitoring networks, are charged with

monitoring natural resources. Vital signs represent a select set of physical, chemical and biological elements and processed of park ecosystems that are chosen to represent the overall health and condition of a park's resources. Together, the Northern and Southern Colorado plateau Networks (NCPN and SCPN) have developed conceptual models of key ecosystems and identified an integrated set of vital signs for tracking resource conditions at 35 NPS units within or near the Colorado Plateau (Thomas et al. 2004, O'Dell et al. 2005). Riparian systems are a high priority vital sign for the NCPN (O'Dell et al. 2005). Riparian systems are disproportionately high in biodiversity relative to their spatial extent due to the year-round or at least frequent availability of water. In turn, healthy and natural riparian systems serve as a predictable source of water, and function to maintain the natural diversity of riparian-adapted plants and animals across the Colorado Plateau region. Various dynamics interact to influence riparian systems. Ground-water levels, flood disturbance intensity and frequency, plant population, dynamics, and even upland conditions and dynamics collectively interact to shape the in-stream conditions and vegetative features of a riparian zone. Monitoring the status and trends in representative attributes and effects of an array of patterns and processes is an overarching goal of the NCPN Integrated Riparian Monitoring effort. This effort is intended to provide park managers with information on the variability of riparian systems, and to provide early warning of system degradation. In the latter case, monitoring information can be used to determine the potential for mitigating actions, and where such actions are implemented, monitoring efforts can contribute to understanding the effects of these actions.
Riparian monitoring occurs in Courthouse Wash in ARCH. Specific objectives of the overall riparian monitoring effort are to determine the status and trends in:
1) the areal extent, cover, species composition and structure of riparian vegetation
2) exotic plant species
3) channel morphology of surveyed cross sections and the channel thalweg
4) floodplain ground-water levels and stream flow/discharge
Procedures for riparian monitoring incorporated pieces of the USGS Water Quality Assessment Program (Moulton et al. 2002) and EMAP procedures (Kaufmann et al. 1999) and were initially developed by Scott and Reynolds (draft). Further refinement has been completed by NCPN staff and by Steve Monroe and Ellen Soles of the SCPN. NCPN riparian protocols have been submitted for peer review.
Findings/Accomplishments for 2011: NCPN field crews established and sampled vegetation at Reach 7, and re- sampled vegetation at Reach 2 in Courthouse Wash. Geomorphology surveys were conducted in Reach 1 and Reach 2. Hydrologic data were collected in the spring. The instream well was frozen in late fall, but data were collected from the riparian piezometer.

6) Study Title: Dust Deposition and Wind Erosion Measurements, Arches NP
Permit No.: ARCH-2011-SCI-0006
Principal Investigator: Marith Reheis
Purpose of Scientific Study: The eastern Colorado Plateau is an area that is vulnerable to wind erosion due to its semiarid climate and sandy soils. Many of the nutrients in these soils have been contributed over thousands of years by additions of aeolian dust from both local and distant sources. Loss of these nutrients by wind erosion depletes the soils and potentially stresses native vegetation. This proposal is to maintain, and monitor for many years, an existing site near Devils Garden with instruments that measure horizontal aeolian sediment transport (using a BSNE) and vertical dust deposition (marble dust traps), as part of a regional study with several other monitoring sites in Canyonlands National Park and surrounding BLM lands.
Findings/Accomplishments for 2011: Samples were collected from the Devils Garden (CP-3) site three times during 2011: early March, early June, and early November. BSNE samples were weighed and discarded. Dust trap samples were analyzed by USGS for

weight, soluble salt content, particle size, and total carbon and inorganic carbon contents (the latter still in process at a contract laboratory).

7) Study Title: U.S. Geological Research in Arches NP (NOTE: this is a continuation of previous studies ARCH-0008 and ARCH-0046.)
Permit No.: ARCH-2011-SCI-0007
Principal Investigator: Jayne Belnap
Purpose of Scientific Study: Maintaining native plant communities, biocrusts (composed of cyanobacteria, lichens, and mosses), soil stability and normal water and nutrient cycles in desert systems is critical to healthy ecosystem functioning. These particular ecosystem processes are threatened by climate change (both altered temperature and precipitation), the compressional forces generated by the trampling of people and offroad driving, and invasive plants (especially annual weeds).
Climate change: Temperatures are expected to rise by up to 6 oC by the year 2100 in this region. Models predict precipitation to show up to a 20% decline. Even with no change in precipitation, higher temperatures will decrease soil moisture by around 30%, stressing plants, biocrusts and altering nutrient cycles.
Compressional forces: Soil compaction and disruption of biocrusts via trampling can result in decreased water availability to vascular plants through decreased water infiltration and increased albedo with possible decreased precipitation. Surface disturbance also generally causes accelerated soil loss through wind and water erosion, with a concomitant decline in soil fertility, and decreased diversity and abundance of soil biota. In addition, loss of biocrusts will lower nitrogen and carbon inputs and slow the decomposition of soil organic matter, resulting in lower nutrient levels in associated vascular plants. Cold desert systems are likely to be especially susceptible to these disruptions, due to the paucity of surface-rooting vascular plants for soil stabilization, fewer nitrogen-fixing higher plants, and lower soil temperatures, which slow nutrient cycles.
Invasive annual plants: Many sites on the Colorado Plateau have been, or are being, invaded by annual weeds. Most of these sites have deep soils and were dominated by perennial grasslands before this invasion. Understanding what factors facilitate invasion; the impact of these invasions on native plants, biocrusts and soil nutrient cycles; and whether sites can recover naturally or need intervention is important in management of these sites. Desert soils may recover slowly from surface disturbances, especially given the expected reduction in soil moisture which is needed for recovery of soils, plants and biocrusts.. Recovery from compaction and decreased soil stability is likely to be very slow. Reestablishment rates for soil bacterial and fungal populations are not known. The nitrogen fixation capability of soil requires at least 50 years for recovery. Recovery of crusts can be hampered by large amounts of moving sediment, and re-establishment can be extremely difficult in some areas. Areas invaded by annual weeds may never recover without restoration efforts.

This project addresses how climate change, land use, invasive of annual grasses and the interaction among these components will affect native plants, biocrusts, and soil nutrient cycling. There are four subsets of studies going on within the park to answer how soils, biocrusts, and plants will respond to 1) climate change on dust production (BSNE network) and 2) land use and climate change (trample plots).
Note: This is a continuation of existing permits: ARCH-00008 (ARCH-2010-SCI-0012) and ARCH-00046 (ARCH-2010-SCI-0003).
Findings/Accomplishments for 2011: We collected dust from BSNEs at three sites in Arches in spring (March), summer (late June), and Fall (late Oct). Dust amounts ranged from 1.6 to 7.5 grams over the year with amounts steadily increasing from spring through fall. Dust levels were 3 times greater at 15 cm than at heights of 50 and 100 cm.

Trample plots were resampled in July 2011 for vegetation cover, cryptobiotic crust cover and soil stability. Plant and soil samples are being analyzed for nutrient content. All data will be summarized and analyzed once results are returned from the soil lab.

8) Study Title: Examining soil and vegetation impacts of magnesium chloride application on roads and trails in Arches National Park
Permit No.: ARCH-2011-SCI-0008
Principal Investigator: Scott Hoffman
Purpose of Scientific Study: The application of $MgCl_2$ as a dust suppressant on unpaved roads is a preferred management option due to its ease of use, efficacy, and low cost. The relationship between these benefits and potential detrimental ecological effects is a relatively unexplored area of research, certainly so within the unique soil, vegetation, and climate characteristics of the Colorado Plateau ecosystem. This study aims to investigate whether the use of $MgCl_2$ in the national parks of the Colorado Plateau ecoregion might lead to certain ecological impacts, and if so, whether the impacts outweigh the advantages of $MgCl_2$ use. The proposed research will investigate the following: 1) the extent to which $MgCl_2$ and its ionic constituents Mg^{2+} and Cl^- are transported by wind and water away from unpaved roads on which it is applied; 2) the current community composition of vegetation in experimental onsite/roadside areas of $MgCl_2$ application; 3) qualitative and quantitative evaluations of onsite/roadside vegetation health; 4) qualitative and quantitative evaluations of offsite vegetation health at established distances away from the treated roadway, based on extent of transport and on landforms present; 5) the onsite and offsite factors that may influence observed changes in soil and vegetation health, and develop a state-and-transition model for the experimental system; and 6) laboratory greenhouse studies to quantitatively examine the effects of $MgCl_2$ application in a controlled setting. The final and broader objective this research will meet will be to collaborate with NPS personnel to develop a long-term monitoring protocol and best practices management guidelines for the ongoing application and environmental impact assessment of $MgCl_2$.
Findings/Accomplishments for 2011: Soil sampling was conducted at specified distances from the Salt Valley Road (SVR) and at specified depths both prior to and immediately following $MgCl_2$ application. Subsequent soil sampling was conducted in November and December. Analysis of soil samples to examine soil variability within the site, and to measure initial transport of Mg^{2+} and Cl^- through the roadside soil is currently underway, and will be completed in June, 2012. Big Spring Number Eight (BSNE) aspirated dust samplers were purchased, painted to match the surrounding landscape, and installed within the study sites at specified distances from the SVR. These were used to conduct vehicular pass experiments in June-Aug 2011 to measure dust emission from the SVR under different traffic loads. Dust samples were collected, weighed, and analyzed for particle size distribution (destructive) for each BSNE bucket distance and height. Particle fractionation of these samples will be completed in April 2012. Further emission analysis will be conducted from April-Sept 2012, and traffic load will be monitored throughout the season.

9) Study Title:
Permit No.: ARCH-2011-SCI-0009
Principal Investigator: I&M (NCPN)
Purpose of Scientific Study:
Findings/Accomplishments for 2011:

10) Study Title: Paleontological Resources Inventory and Monitoring at Arches National Park
Permit No.: ARCH-2011-SCI-0010
Principal Investigator: Jim Kirkland
Purpose of Scientific Study: The geology and a stratigraphic section of Arches National Park has been documented and reviewed by Doelling (1985, 2001, 2003).
While 1 X 50,000 scale geological mapping of the park is complete with a more recent highly resolved 1 X 100,000 map of the area published, the 1 X 25.000 scale geological mapping of the entire park is in the final review stage at the Utah Geological Survey. With additional ground truth for justification, these maps provide the framework for developing detailed Potential Fossil Yield Classification (PFYC) maps for Arches National Park (Kirkland and others, 2005). A baseline paleontological inventory of Arches National Park was undertaken by the National Park Service between 2002 and 2004 (Swanson and others, 2005). This study focused on previously known sites and spending 3 days inventorying the Upper Jurassic Morrison Formation and Lower Cretaceous Cedar Mountain Formation resulting in the discovery of several new and highly significant sites, including ; an Apatosaurus skeleton at the top of the Morrison Formation and (Foster, 2005) and an extensive tracksite in the Cedar Mountain Formation (Lockley et al., 2004). While, the dinosaur site has been stabilized and is in the back country, the tracksite is not fully documented, fragile (highly fractured rock on steep slope), and is near the parking area and the beginning of the trail to Delicate Arch.. Thus, this site is in dire need of a monitoring plan. Additionally, while the transition between the Chinle Formation and the oerlying Glen Canyon Group is known to be highly fossiliferous in the area immediately surrounding Arches National Park (Lockley and Gerlinski, 2009; Santucci, and Kirkland, 2010; numerous observations and interviews by Kirkland). Additionally the UGS paleontological team found that this interval preserved the majority of the significant paleontological localities at Zion National Park (DeBlieux et al. 2006). These rocks have never been prospected for fossils within Arches National Park and are well exposed along the south and west sides of Salt Valley for the length of the Park. Therefore, it is proposed to gather additional data and establish a monitoring plan for the tracksite near the start of the Delicate Arch Trail following the general methodologies established by Kirkland and Foster (2006)and Santucci and others (2009). The UGS will to prospect the outcrop belt of the Chile-Kayenta Formations to establish the density and distribution of fossil recourses in these strata. It is predicted that numerous track sites and some skeletal sites will be identified. In both of these parts of the project surface collection of fossils may be made for further analysis and their protection in accordance to NPS policies.
Findings/Accomplishments for 2011: Three weeks of field work was complete in the fall of 2011. 41 new paleontology sites were recorded more that doubling the known paleontological resources in Arches National Park. Approved collections were minimal; Fragments of theropod (14 small pieces) from Kayenta Formation (First Kayenta dinosaur found in Utah)from ARCH71v); A small Phytosaur tooth from the basal Wingate Sandstone (Arch65v), amd an approximately 10X10' slab of 1' thick sandstone preserving a proxy specimen of a new trace fossil still to be described from the lower Ruby Ranch Member of the Cedar Mountain Formation (ARCH 7t) . All three specimens have been curated into the Arches National Park collection and are on loan for further study.
Final report is in the process of being written.

11) Study Title: Structural Study of the Moab Fault in the Arches NP Entrance Area
Permit No.: ARCH-2011-SCI-0011

Principal Investigator: Haakon Fossen
Purpose of Scientific Study: The purpose of this study is to describe in detail the geometric and petrophysical aspects of the Moab Fault and related structures in the area around the Arches National Park Visitor Center. This is an area that is visited by hundreds of geologists every year, and an exceptionally well exposed example of a large-scale (900-1000 m offset) salt-related fault. The primary purpose is to build a detailed 3D model of the area based on LIDAR (LIght Detection And Ranging) scanning. Geometric aspects of the geologic layers (primarily the Entrada and Navajo sandstones) and fault structures will later be interpreted based on the LIDAR scans. This means that structures and bed thickness (variations) can be measured accurately even in cliff faces where physical access is practically impossible. Secondly, we wish to add information about the rocks and their structures by means of observations and sampling in the field, notably along the road cuts (see summary of field activities below). The project will be displayed on a website when the results are analyzed, probably one connected to my professional website (http://folk.uib.no/nglhe/). Scientifically the purpose is to increase our understanding of faults and faulting in sandstones in general and above salt structures in particular. This has practical implications for our understanding of many petroleum reservoirs worldwide, in addition to our general understanding of faulting in clastic sedimentary sequences.
Findings/Accomplishments for 2011: Lidar data have been collected as planned. These data are being processed so that they can be used to study the area by means of a computer in 3D. Thin sections remain to be prepared from collected samples. Analyses remain to be done. Permeability data have been plotted, showing how permeability gradually decreases in a 30 m zone around the fault.

12) Study Title: Assessing Climate Refugia and Connectivity for Desert Bighorn Sheep
Permit No.: ARCH-2011-SCI-0012
Principal Investigator: Clinton Epps
Purpose of Scientific Study: (Note: the Detailed Implementation Plan for this study has been signed by Kate Cannon, the Superintendent of the Southeast Utah group, and Jeff Troutman, formerly the Resource Management Division Chief for the Southeast Utah group.) Management of wide-ranging species with fragmented distributions offers a difficult challenge on NPS lands, particularly in the face of regional or global shifts in climate. Desert bighorn sheep (Ovis canadensis nelsoni) exemplify that challenge. This charismatic, desert-adapted animal exists in relatively small, sometimes isolated populations scattered across the arid southwestern United States. Recent research has firmly linked desert bighorn sheep persistence and genetic diversity with climate variation (Epps 2004; Epps et al. 2004, 2006), and reproduction and survival for this species are predicted in large part by precipitation and temperature (Wehausen 2005). However, high rates of population extinction (e.g., Wehausen 1999) may be mitigated by recolonization from other nearby herds (e.g., Epps et al. 2010). While climate is intractable to management at the regional level, maintaining connectivity among existing populations of bighorn sheep will provide the best means for offsetting the unpredictable but potentially devastating changes in precipitation and temperature predicted for the American southwest. Historically, management of desert bighorn sheep was approached on a population by population basis. Growing recognition that desert bighorn sheep are subject to metapopulation dynamics (frequent extinction and recolonization of small populations in discrete habitat patches) has made it clear that desert bighorn sheep must be managed at a regional level. This is particularly true given that many processes that affect bighorn sheep, such as climate variation or climate change, are correlated at regional scales. Human-driven landscape change is also happening at an unprecedented scale, as demonstrated by proposed massive solar developments in the Mojave Desert and the US-Mexico border fence (Flesch et al. 2010). National Park Service lands support significant populations of desert bighorn sheep

in at least nine parks in four states. However, in many cases the connectivity of those populations and with other populations in each region is unclear. Also unclear are the roles of those herds in regional context: are they core populations, peripheral populations, or do they serve as a critical link for gene flow and dispersal between other populations in the region? Lastly, although region-level predictions from global climate change models are often highly variable, how will anticipated changes in temperature and precipitation affect desert bighorn metapopulation structure and habitat? Despite these uncertainties, ongoing research on desert bighorn sheep has created unprecedented opportunities to evaluate the role of bighorn sheep populations on NPS lands in the context of metapopulation persistence and climate change. We propose to use a combination of new and existing datasets to 1) analyze genetic diversity and metapopulation structure of desert bighorn on NPS and pertinent surrounding lands; 2) optimize connectivity models by augmenting existing genetic datasets; 3) explore metapopulation persistence under different climate change scenarios; and 4) identify regional refugia for desert bighorn sheep in the context of NPS lands and climate change.
Findings/Accomplishments for 2011: We collected over 500 bighorn sheep fecal samples from national park lands and adjacent public lands in 2011 for genetic analysis. No samples were collected from Arches NP in 2011, although several days were spent searching for bighorn sheep with no success. The majority of fieldwork in 2011 was focused in other NPS units, but substantial fieldwork in Arches NP is anticipated in 2012.
Fecal samples will be genotyped and genetic data will be analyzed, in combination with previously collected/genotyped samples, to reveal genetic structure of desert bighorn sheep populations in and near national park lands. A spatial database and full report including locations of fecal samples, group sizes and locations of bighorn sheep observations, genetic data, and important waterholes will be provided to NPS at the completion of the study.

13) Study Title: Nitrogen deposition in the National Parks of the Four Corners region
Permit No.: ARCH-2011-SCI-0013
Principal Investigator: Sasha Reed
Purpose of Scientific Study: Nitrogen (N) deposition in the western U.S. is on the rise and is significantly affecting terrestrial ecosystems. For example, N deposition has repeatedly been shown to lower air quality, increase greenhouse gas emissions, alter plant community composition, reduce water quality, and significantly modify fire regimes. Accordingly, the effects of N deposition represent one of our largest environmental challenges and make difficult NPS's mission to "preserve the scenery and the natural and historic objects and the wildlife…unimpaired for the enjoyment of future generations". Due to increased population growth and energy development, the Four Corners region has become a notable 'hotspot' for N deposition, however, our understanding of how increased N deposition will affect these unique ecosystems remains notably poor. This project represents multi-disciplinary approach to gathering information that will help NPS safeguard the Four Corner's national parks, both now and into the future. We will use modeling, field, and laboratory techniques to clarify current N deposition gradients and to elucidate the ecosystem consequences of N deposition to the national parks of the Four Corners. This work will ultimately lay the foundation to elucidate thresholds and deposition effects on soil and plant communities and will provide the basis for upcoming field fertilization experiments to link N deposition, exotic plant invasion, fire regimes, and ecosystem function in the national parks of the Four Corners region.

Findings/Accomplishments for 2011: The majority of findings in this year resulted from laboratory incubations using soils collected outside of Arches National Park, but associated directly with this project. In the lab, we found that biological soil crusts from near Arches fixed less nitrogen than crusts found in Mesa Verde National Park. We also found that, when crusts here were fertilized with increasing amounts of nitrogen, nitrogen additions rapidly

reduced nitrogen fixation rates in Mesa Verde soils, while nitrogen fixation from local soils was actually stimulated by nitrogen additions. In other words, the Mesa Verde soils that receive much higher loads of nitrogen deposition seemed to respond to excess nitrogen by down-regulating nitrogen fixation rates, while the soils from our area did not. The reason behind the increased nitrogen fixation in the face of increased nitrogen inputs remains unknown, but we are currently working up data that may help shed some light on the finding. Along with nitrogen fixation rates, simultaneously assessed sample soil nutrient availability (nitrogen and phosphorus), as well as soil phosphatase activity. We hypothesize that interactions between nitrogen and phosphorus cycling could be responsible for our observation, yet these data need further analysis to test our hypothesis.

The fertilization plots we set up last fall in Arches NP have not yet yielded as many results as the incubation study, but we are very excited to see what happens this year. We did find textural variation at our three sites in the Park, as well as variation in nitrogen and phosphorus availability (although all soils had low concentrations for both). We hope to complement these data with two more soil sampling points that will better integrate seasonal variability. We have not yet observed any of the *Bromus tectorum* we planted in the plots begin to grow, but we hope to continue to look for this, as well as chemical changes in soil and plant material in the upcoming year.

14) Study Title: Deformation band fault evolution in the Curtis Formation, Arches National Park
Permit No.: ARCH-2011-SCI-0014
Principal Investigator: Simon Kattenhorn
Purpose of Scientific Study: The proposed study will examine the evolution of a type of geologic deformation structure called a deformation band fault. This is a tectonic deformation style caused by extension of sandstones in the Moab Anticline. As the rock is extended by the folding, faults start to form in the style of deformation bands. We will study this process, from the creation of a single deformation band to the development of a major fault zone, by examining fully exposed (tip-to-tip fault exposure), small faults in the Curtis Formation in the Rough and Rocky Mesa region of Arches National Park.
Findings/Accomplishments for 2011: Field work was undertaken and completed in October 2011 in the designated field area. Student Alex Brekke made field observations of deformation band fault locations and characteristics to be used in the scientific analysis (continuing). The goal is to determine variations in deformation band style, thickness, and offset as a function of location relative to the fault tip. This will provide information on the ability of low-slip faults to break down rock grains and reduce porosity of the sandstone. To assist in this analysis, Alex collected 5 samples for thin section analysis. These thin sections are being kept at the University of Idaho and have been assigned NPS specimen catalog numbers (Accession number ARCH-00406; Catalog #s ARCH 3818-3822). No actual rock samples have been retained (destroyed during thin section production). Thin section analyses have indicated the progressive cataclastic breakdown of grains and reduction of porosity with increasing distance away from the fault tip; however, even a single deformation band can effectively reduce porosity very close to the fault tip. The scientific results are currently being written up for a Senior thesis project and will subsequently be evaluated for publication in a scientific journal by Simon Kattenhorn.